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A Preliminary Exploration of the Canadian Observer and Catch-effort Data on Bycatches of 3Ps Cod.

Étude préliminaire des données d'observateurs canadiens et des données de captures et d'effort sur les prises accessoires de morue dans 3Ps.

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ABSTRACT

The Canadian observer data for the period from 1985 to 2001 were used to investigate bycatches of 3Ps cod. The catch-effort data from 1998-2001 were merged with the observer data to flag the observed and unobserved catches by year, cfv (commercial fishing vessel), month, and day. The present study is focused on identifying temporal and spatial variability of bycatches of cod and their dependence on directed species and gear types. The study revealed a significant decline in bycatches of cod from the pre- to post- moratorium periods. Prominent seasonal variations were characterized by the high winter bycatches. The bycatches of cod vary significantly with directed species, with American plaices predominant before 1994 and witch flounders largest afterwards. Gear types have large impacts on the bycatches with dominant bycatches from otter trawl over the entire study period and a significant portion from gillnet from 1993 onward. There were considerable variations in bycatches among unit areas, generally more offshore than inshore.

RÉSUMÉ

Nous utilisons les données d'observateurs de 1985 à 2001 pour étudier les prises accessoires de morue dans 3Ps. Nous combinons ces données avec les données de captures et d'effort de 1998 à 2001 pour mettre en évidence les captures observées et non observées par année, par bateau de pêche commerciale, par mois et par jour. Cette étude met l'emphase sur l'identification de la variabilité spatiale et temporelle des prises accessoires de morue, ainsi que leur dépendance à l'égard des espèces visées et des types d'engins. Nous montrons que les prises accessoires de morue ont significativement baissé de la période précédant le moratoire à celle après le moratoire. Les grandes variations saisonnières étaient caractérisées par des prises accessoires élevées l'hiver. Les prises accessoires de morue variaient significativement selon l'espèce visée par la pêche : elles étaient les plus élevées pour la pêche dirigée de la plie canadienne avant 1994 et pour la pêche de la plie grise par la suite. Le type d'engin influe beaucoup sur les prises accessoires : celles-ci étaient les plus élevées pour les chaluts à panneaux durant toute la période à l'étude et étaient importantes pour les filets maillants à partir de 1993. Les prises accessoires variaient considérablement d'un secteur de pêche à l'autre, généralement davantage au large qu'en milieu côtier. Les prises accessoires n'étaient faites que dans les eaux de moins de 500 m de profondeur avant 1990, mais elles sont surtout faites en eaux plus profondes depuis.

Introduction

The Atlantic cod (Gadus morhua) stock in NAFO Subdiv. 3Ps (Fig. 1) is believed to be a complex mixture of different components that may move seasonally among adjacent areas and migrate seasonally between offshore and inshore, but the contributions of these components to the fisheries are not fully understood (Brattey et al., 2001). Fish are caught offshore by mobile and fixed gear and inshore by fixed gear. The 3Ps cod has undergone different stages and drastic changes in the past 50 years. In the 1960s and early 1970s, the stock was heavily exploited by non-Canadian fleets, mainly from Spain, with catches peaking at 84,000 t in 1961 (Brattey et al. 2001). After the extension of jurisdiction in 1977, catches averaged around 30,000 t until the mid-1980s when fishing effort by France increased and total landings reached about 59,000 t in 1987. Catches then declined gradually to 36,000 t in 1992. In August 1993, a moratorium was imposed after only 15,000 t had been landed. In May 1997, the fishery reopened with a TAC (total allowable catch) of 10,000 t. The TAC was subsequently increased to 20,000 t for 1998 and to 30,000 t for 1999. For 1 April 2000 to 31 March 2001(management year) the TAC was set at 20,000 t. For the 2001-2002 management year, the TAC was set at 15,000 t.

Growing concern and detailed analyses about the status of the 3Ps Atlantic cod were reported in various previous publications (e.g. Pinhorn 1969; Bishop et al. 1991, 1992, 1993, 1994, 1995; Shelton et al. 1996; Stansbury et al. 1998; Brattey et al. 1999a, 1999b, 2000, 2001). These studies were based on data from commercial fisheries and research surveys directed for the Atlantic cod. So far little information has been explored from the bycatches of cod data collected from other directed fisheries in this region. In 1980, the Department of Fisheries and Oceans and industry jointly established the Canadian observer program, using independent observers on board commercial fishing vessels to collect bycatches, discarding and other information. The program has generated useful data for fisheries science, in addition to its principal role of enforcement and control.

In the 3Ps area, the dominant species other than the Atlantic cod are American plaices (Hippoglossoides platessoides), witch flounders (Glyptocephalus cynoglossus), white hakes (Urophycis tenuis), and redfishes (Sebastes). These fisheries have the potential for high cod bycatches (Table 3). A realistic estimation of the total bycatches of cod can be vital to the cod stock assessment.

In this document we use the Canadian observer data from 1985 to 2001 to study the bycatches of 3Ps cod, which will be merged with the commercial catch-effort data. The primary purpose of this study is to examine temporal (seasonal and interannual) and spatial (unit area, depth) variations of bycatches of cod and to investigate impacts of human practices such as the moratorium, directed species, and gear types in 3Ps. The present results may lead to an establishment of appropriate models to estimate total bycatches of cod in a later study.

Data and Methods

Canadian observer data

The Canadian observer data used in this study were collected by Newfoundland-based observers (95%) and by Quebec observers (5%) monitoring fish activities from 1985 to 2001. Data gathered geo-referenced information on fishing operations, including, but not limited to catch and effort, on a set by set basis. The catches of all species taken in the gear were recorded together with latitude and longitude, time, area, depth and other effort information described in Kulka and Firth (1987).

Observed vessel sizes are recorded as tonnage, with 46% of vessels from 500-999.9 tonnage class and 18% of vessels below 25 tonnages. During pre-moratorium, vessel tonnages tend to be larger (all above 50). After moratorium, smaller tonnage vessels (below 50) appear through all the study period.

Commercial catch-effort data

Commercial catch-effort data used in this study were collected from logbooks and purchase slip records and interpreted by Statistics Division, Department of Fisheries and Oceans for the time period 1998 to 2001. The catches (reported landings) of all species taken in the gear were recorded according to different landings (different buyers). In this study, only data from logbooks have been included.

For the commercial catch-effort data during the period of 1998 to 2001, there were total 1011 vessels, among which 182 vessels were observed (18%). Up to 79% of the sets recorded in the catch-effort data are from vessels below 45 feet (Table 1). The largest vessel length (>125 ft) class accounts for 8% of the sets.

Merger of the observer and catch-effort data

In this study the two data sets have been merged according to year, cfv (commercial fishing vessel), month, and day, since trip, set, and time (UTC vs. the Newfoundland Time) were recorded in different standards. The impact of time differences is negligible since we are interested in seasonal and longer-term patterns. Flags distinguishing the observed catches from the unobserved ones have been added. 44% of the sets observed is for vessels above 125 feet (Table 2). This largest vessel length class was observed even more closely in 2000 and 2001 (68%, 52% respectively). Significant factors with respect to bycatches, such as temporal and spatial effects, fishery and gear specifications are identified in the analysis

Catch records from logbooks have been used to compare with the observer' records during 1998 to 2001(Fig. 2). The comparison revealed substantial differences between observers' and skippers' records. The differences will be studied and used to estimate the overall bycatches of 3Ps cod in a later study.

Results and Discussions

For the observer data, a total of 12,820 sets were examined for the occurrence of bycatches of cod in NAFO Subdiv. 3Ps during 1985-2001. Out of this total, bycatches of cod occurred in 7315 sets, which equates to 57%. However, the total number of sets includes pots and scallop dredges with low bycatch capability. In addition, several gear types such as shrimp trawl have been modified over the study time period in order to minimize bycatches (Kulka, 1999). In the early 1990s, many directed fisheries such as American plaices were closed, which could impact the bycatches of cod.

The spatial distribution of observed bycatches of cod including zero sets is illustrated in Fig 3 (pre-moratorium) and Fig 4 (post-moratorium). The temporal and spatial variability of the bycatches of cod is apparent. The bycatches are primarily (94%) related to fisheries directed for American plaice, witch flounder, redfish and white hake (Table 3). In the Halibut Channel and the southern and eastern portion of St. Pierre Bank, there were bycatches in all ranges during pre-moratorium (Fig. 3), from directed American plaice and witch flounder fisheries (Table 3, 4). As a result of the closure of the directed American plaice fishery in this area from Sept. 1993, we see the decline of bycatches in those areas (Fig. 4, Table 3, 4).

The frequency distribution of observed bycatch weight (kg) per set including zero sets is shown in Figure 5. About 60% of the sets captured less than 70 kg including zeros, with more sets of large single bycatches in the pre-moratorium period. In the post moratorium some 70% of the sets captured less than 10 kg including zeros. The total bycatches of cod during the entire study period were 2,147 tons. The average bycatch per set was 167 kg, with a median of only 5 kg, which is in agreement with the asymmetric distribution of Figure 5. The last bar includes all the sets of 790 kg or more.

In the rest of the present section, the bycatches of cod are further discussed by year, month, directed species, gear types, unit areas and depth.

The most striking feature is the high average bycatch in the pre-moratorium period and the low average bycatch afterwards (Fig. 6). The post moratorium mean values decreased to about one-sixth of the pre-moratorium ones. The average weight per set was highest in 1985. Since then, the average bycatch showed significant year-to-year variability (particularly from 1993 to 1994), but had never recovered to the level of 1985. The average bycatch in 1993 remained high, since the moratorium did not begin until August after the high bycatch season. The yearly presence of bycatches of cod among all directed species gradually fell to about one third of its pre-moratorium level (Fig. 6). The overall temporal pattern supports the pre- to post-moratorium decline in the average bycatch. During 1994-1997, the presence of bycatches rose, which might be related with closure of the cod stock and also the decline/closure of the other stocks. As far as total bycatch weight goes, the highest bycatches happened in 1992 and 1993 (Table 3). After 1993 bycatches were generally lower than those in the early period.

The monthly bycatches for 1985 to 2001 are summarized according to gear types (Table 5). Substantial bycatches occurred during January to April (90%). Fishing activities were higher in winter and lower in fall. The bycatch weight was larger in winter and early spring (January to April) and much lower in the other months. Offshore bycatches have come mostly from 3Psh (60%) (Table 4). The bycatches from otter trawl dictated the monthly variability (Table 5).

American plaices were directed species before Aug. 1993 and this fishery were closed afterwards. They accounted for some 74% of total bycatches before 1994 and about 57% for the entire period from 1985-2001 (Table 3). There have been bycatches from directed fisheries for witch flounder and redfish throughout the entire period. Bycatches from directed witch flounder fishery were second only to those from directed American plaice fishery in total and largest in 1993 among all the directed species (Table 3). The dominant position of targeted species was changed from American plaice to redfish. The white hake and skate have stayed as directed species since 1993.

The bycatches from otter trawl during 1985-2001 amounted to 89% of total bycatches (Table 5). Gillnets captured the significant portion of bycatches after 1993 but otter trawl remained dominant for most years (Fig. 7). In general, bycatches declined during the post-moratorium period. The mesh size of gillnets was restricted to a maximum of 6.5 inches during the post-moratorium period to reduce discarding and dumping as a consequence of size and quality based price differentials (Brattey et al. 2001). But gillnetters fishing in the offshore position of 3Ps used larger mesh size to fish for white hake and skate and still kept cod as bycatches (Brattey et al. 2001).

In general, inshore bycatches were very low, accounting for only 4% of total bycatches (Fig. 8, Table 4). The offshore bycatches were much higher, especially in 3Psh (60% of total bycatches) with the main species sought being American plaices. In 1985 there were a few largest sets with bycatches 15 tons in the Laurentian Channel. Starting from 1994, bycatches were lower than those in the previous years (Fig. 4). Inshore bycatches in 3Psa showed an overall increase. Relatively high bycatches were again in offshore areas, especially in 3Psh. Unit area 3Psd was closed to directed cod fishery from 15 November to 15 April during 1998-1999, 1999-2000, and 2000-2001, based on the possible mixing of northern Gulf cod into the 3Ps stock area at this time of year (Brattey et al. 2001).

The observer data were binned according to water depth from 0 to 800 m, with an interval of 50 m. The depth distribution of Atlantic cod averaged over 1993-2001 indicates that waters shallower than 500 m is a preferred habitat for cod in 3Ps (Fig. 9). The depth occupied is usually related to temperature. Cool temperatures are preferred, generally in the range of –0.5 to 10 °C (Scott and Scott, 1988). However, no information is available about the water temperature for individual sets in observer data. The bycatch per unit effort (BPUE) from the three commercial gears (kg per hour for otter trawl, per 1000 hooks for longline and per 100 nets for gillnets) has been illustrated in Fig. 9. It is noticeable that BPUE from otter trawl agrees with the trend from the average weight per set. There is

striking variability in gillnet catch rate, highest with water depth of 150-250 m. BPUEs from both longline and gillnet at depth greater than 500 m are zero during these years. The proportion of sets with cod also indicates strong depth dependence of the cod abundance, significantly higher shallower than 500 m.

During 1985-1993 (pre-moratorium), most of fishing activities occurred in shallow waters (<=500m) (Fig. 10, Table 6). About 88% of total bycatches for 1985-2001 was from the depth below 500 m, of which 80% was from pre-moratorium. There were a couple of largest sets (15 tons) at the depth between 50 to 200 m. It is noted that since 1990 bycatches have been found mostly from depth greater than 500 m, suggesting that the cod may have moved from shallower to deeper, or after 1990 most of fishing vessels were in offshore (Table 1, 2), or the commercial vessels can't reach the inshore components of the stock.

Summary

In this document we have demonstrated a significant decline of bycatches of cod in NAFO Subdiv. 3Ps area from the pre- to post- moratorium periods, based on the 1985-2001 Canadian observer data. In addition to this drastic shift, there were substantial interannual differences with higher bycatches in the 80s. Prominent seasonal variations were characterized by the high winter bycatches. There were considerable variations of bycatches among unit areas, generally more offshore (3Psh) than inshore. Depth dependence of cod bycatches was evident. Bycatches were in waters shallower than 500 m only before 1990, but in deeper waters mostly since then.

The bycatches of cod varied significantly with directed species. Large bycatches were found in directed fisheries for American plaice, witch flounder, redfish and white hake. The total bycatches were mainly from directed fisheries for American plaice before 1994. Bycatches from witch flounder were second only to American plaice in total and largest in 1993 among all the directed species. Gear types have large impacts on the bycatches, with high bycatches from otter trawl throughout the period. Significant portion of bycatches were caught by gillnet after 1993.

The present exploration also indicates a problem to analyze weight differences (per set) between observers' and skippers' records. Weight per set in catch-effort data is not strictly kept on the basis of sets. For example, if a fisher reported fishing activities in detail, he recorded an estimate of catch for each tow of the otter trawl. Generally for Gillnets, he did not report in such level of detail. The fisher usually recorded total catches from all gillnets per day and sometimes per trip (Hollahan C. Newfoundland region, personal communication, 2003). However, observer recorded data on year, trip and set basis. Nevertheless, the present analyses of the Canadian observer data have identified some robust factors (year, season, unit area, gear type, directed species, depth and effort) of bycatches of cod in 3Ps area. Generalized linear models can be applied to the observer bycatch data by taking into these factors account, such as time, area, directed species, gear types and effort factors. The model can be used to predict total bycatches for catch-effort data in otter trawl fishery.

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Table 1: Number of all sets by year and vessel length including zero bycatches in catch-effort data.

Year	1-34.9	35-44.9	45-64.9	65-99.9	100-124.9	125+	Total
1998	419	2348	989	260	74	516	4606
1999	6377	2167	617	216	0	549	9926
2000	5384	2573	417	135	0	732	9241
2001	51	2590	595	265	6	469	3976
Total	12231	9678	2618	876	80	2266	27749
Percent	44%	35%	9%	3%	0%	8%	

Table 2: Number of sets being observed by year and vessel length in catch-effort data.

Year	1-34.9	35-44.9	45-64.9	65-99.9	125+	Total
1998	8	68	40	70	95	281
1999	95	61	13	53	26	248
2000	11	43	4	30	189	277
2001	2	97	77	106	309	591
Total	116	269	134	259	619	1397
Percent	8%	19%	10%	19%	44%	

Table 3: Observed yearly bycatches (kg) from NAFO Subdiv. 3Ps by directed species. A value of 0 indicates no bycatch, and an NA indicates no data available.

Year	Redfish	Plaice	Witch	white_hake	Skate	Others	Total
1985	2179	190986	105	Na	Na	0	193270
1986	51524	55618	10230	Na	Na	2212	119584
1987	50	6269	0	Na	Na	0	6319
1988	2069	23751	581	Na	Na	7119	33520
1989	1890	120853	5800	Na	Na	10917	139460
1990	4010	297100	3898	Na	Na	605	305613
1991	4027	81803	68088	Na	Na	13744	167662
1992	2351	329311	16925	Na	Na	4269	352856
1993	4555	128146	168417	36487	2487	866	340958
1994	29703	Na	8446	2765	477	1401	42792
1995	6350	Na	1059	7195	0	4024	18628
1996	9110	Na	16617	2691	16	4312	32746
1997	8779	Na	20748	2418	42	18554	50541
1998	10353	Na	29138	5340	5986	1302	52119
1999	6857	Na	37843	98	720	757	46275
2000	5821	Na	5225	15038	590	766	27440
2001	20064	Na	155415	44	4086	37799	217408
Total	169692	1233837	548535	72076	14404	108647	2147191
Percent	8%	57%	26%	3%	1%	5%	

Table 4: Observed yearly bycatches (kg) of cod from NAFO Subdiv. 3Ps by unit area.

Year	3Psa	3Psb	3Psc	3Psd	3Pse	3Psf	3Psg	3Psh	Total
1985	752	310	0	19717	33380	87135	44620	7356	193270
1986	5315	0	0	58608	2129	4940	22682	25910	119584
1987	50	0	0	0	0	65	0	6204	6319
1988	0	9188	0	275	0	6702	601	16754	33520
1989	1143	5582	112	5024	290	3285	30157	93867	139460
1990	1305	105	13	50796	22226	19786	84517	126865	305613
1991	2910	11060	0	281	421	9841	14873	128276	167662
1992	10	3614	0	2466	134	1373	96639	248620	352856
1993	3065	1116	0	413	443	20	12080	323821	340958
1994	11589	934	1366	17113	2	0	45	11743	42792
1995	2812	3492	259	610	0	0	10	11445	18628
1996	2199		0	6911	32	0	5	23599	32746
1997	4868	14275	1184	4988	3	2133	676	22416	50541
1998	931	0	0	6837	0	0	8915	35436	52119
1999	696	339	387	3026	16	3086	4663	34062	46275
2000	1573	23	310	3745	0	3095	951	17743	27440
2001	6678	935	144	12570	910	702	21668	173801	217408
Total	45896	50971	3775	193380	59986	142163	343102	1307918	2147191
Percent	2%	2%	0%	9%	3%	7%	16%	61%	

Table 5: Observed monthly bycatches (kg) from NAFO Subdiv. 3Ps by gear type for 1985-2001.

Month	Otter trawl	Gillnet	Longline	Midwater trawl	Shrimp trawl	Others	Total
Jan	272919	526	28649	21665	0	0	323759
Feb	530878	923	5930	15311	0	0	553042
Mar	771266	2695	4034	14178	2	6	792181
Apr	211266	37388	28	13454	0	336	262472
May	54369	3260	4267	1377	860	615	64748
Jun	23151	6669	0	0	2409	555	32784
Jul	12734	10009	5	0	4019	145	26912
Aug	11740	14454	745	3	6948	11	33901
Sep	5450	6199	276	0	5207	63	17195
Oct	3614	19352	421	0	5725	26	29138
Nov	3477	3122	39	46	1121	447	8252
Dec	2437	0	0	370	0	0	2807
Total	1903301	104597	44394	66404	26291	2204	2147191
Percent	89%	5%	2%	3%	1%	0%	

Table 6: Observed yearly bycatches (kg) from NAFO Subdiv. 3Ps by depth. Percent1 is the ratio of the yearly to total bycatch. Percent2 is the ration of the depth-binned to total bycatch.

Year	Bycatch at <=500m	Sets at <=500	Bycatch at >500m	Sets at >500m	Total	Percent 1
1985	193270	298			193270	9%
1986	119584	288	0	1	119584	6%
1987	6319	26			6319	0%
1988	33520	321			33520	2%
1989	139460	732			139460	6%
1990	304893	788	720	4	305613	14%
1991	164731	823	2931	8	167662	8%
1992	338631	1201	14225	9	352856	16%
1993	205347	624	135611	238	340958	16%
1994	41142	979	1650	13	42792	2%
1995	16469	745	2159	68	18628	1%
1996	17443	523	15303	78	32746	2%
1997	37153	771	13388	63	50541	2%
1998	34058	888	18061	72	52119	2%
1999	45358	904	917	69	46275	2%
2000	26695	613	745	62	27440	1%
2001	161136	1441	56272	170	217408	10%
Total	1885209	11965	261982	855	2147191	
Percent 2	88%		12%			

Figure 1. NAFO Subdivision 3Ps management unit, boundaries of French zone and main fishing areas.

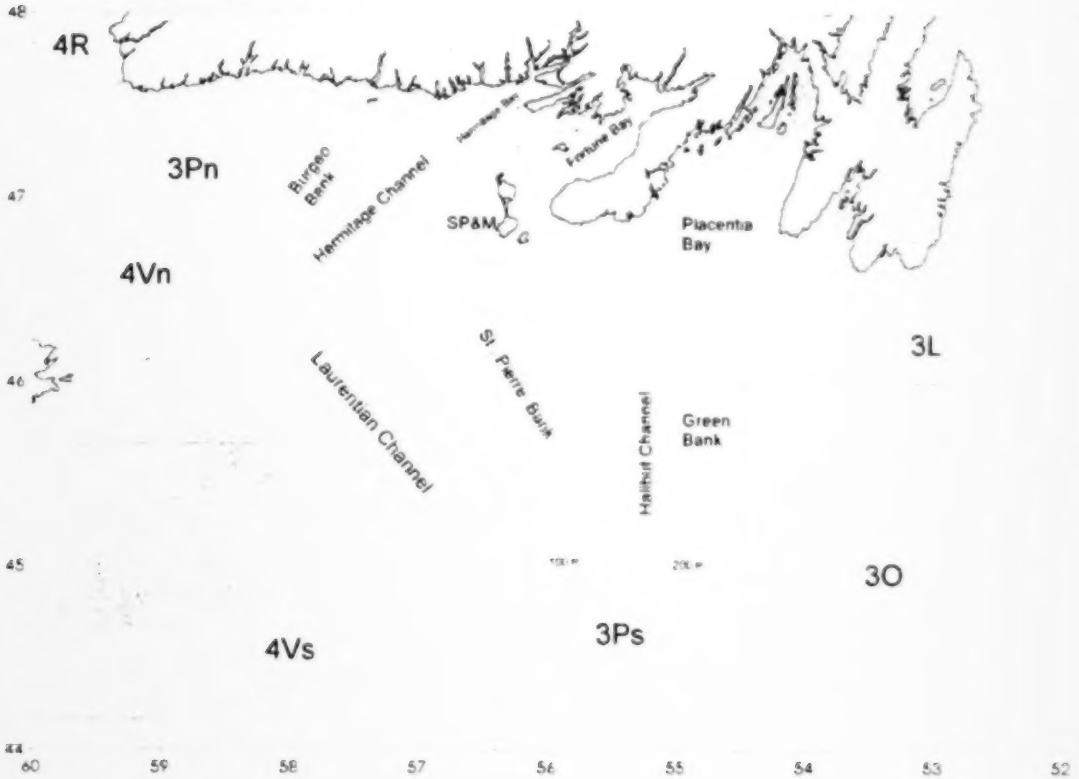


Figure 2. Annual total bycatches from observer data and logbooks in NAFO Subdiv. 3Ps.

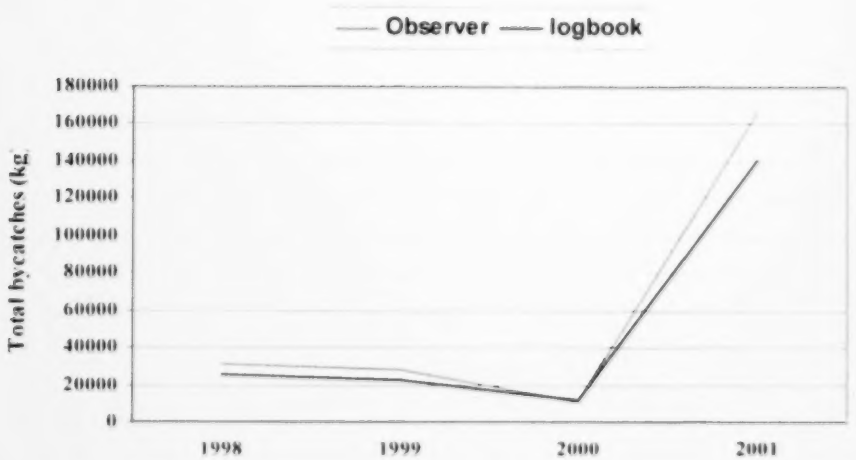


Figure 3. Spatial distribution of observed fishing sets with bycatches of cod (including zero sets) from 1985 to 1993.

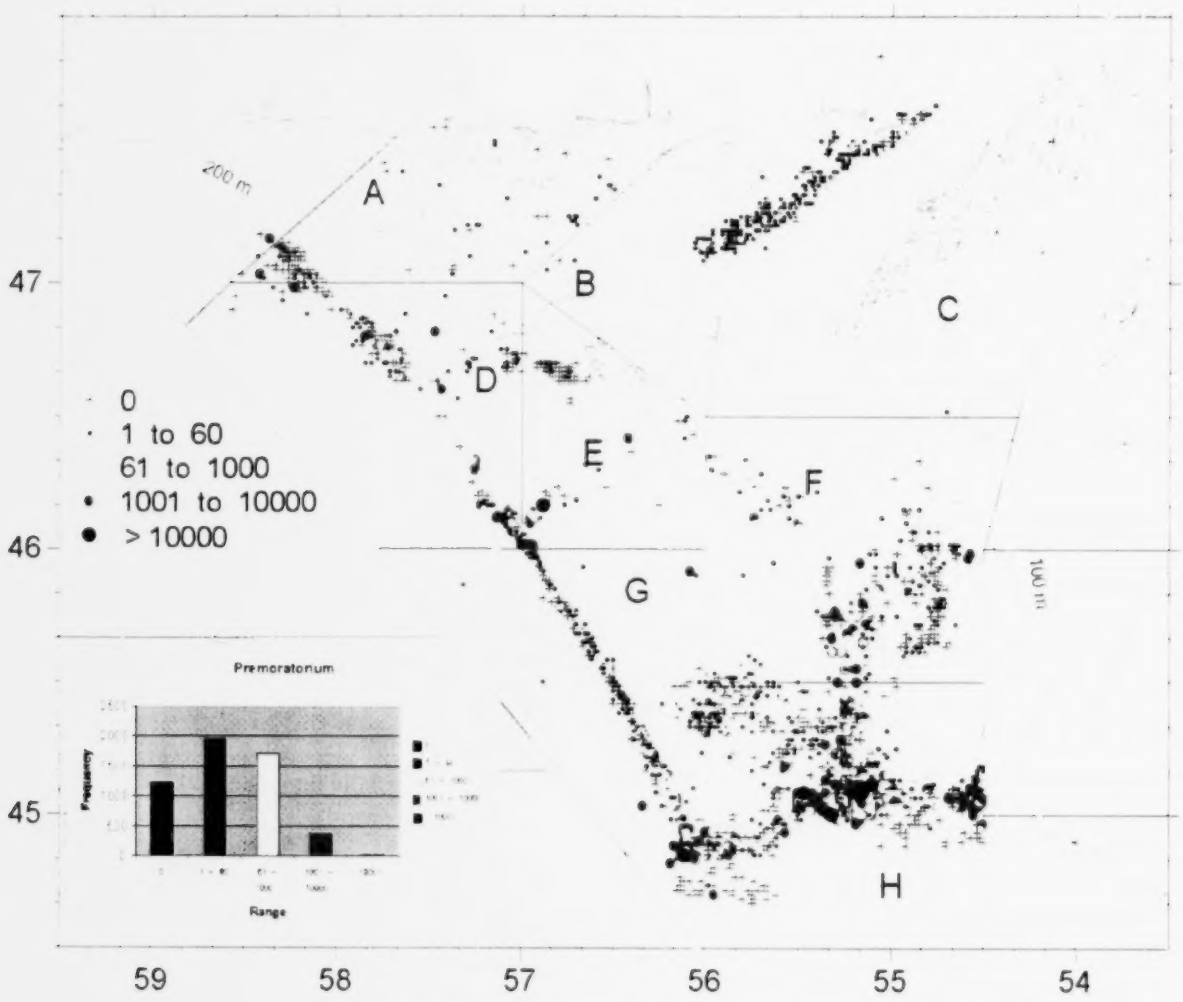


Figure 4. Spatial distribution of observed fishing sets with bycatches of cod (including zero sets) from 1994 to 2001.

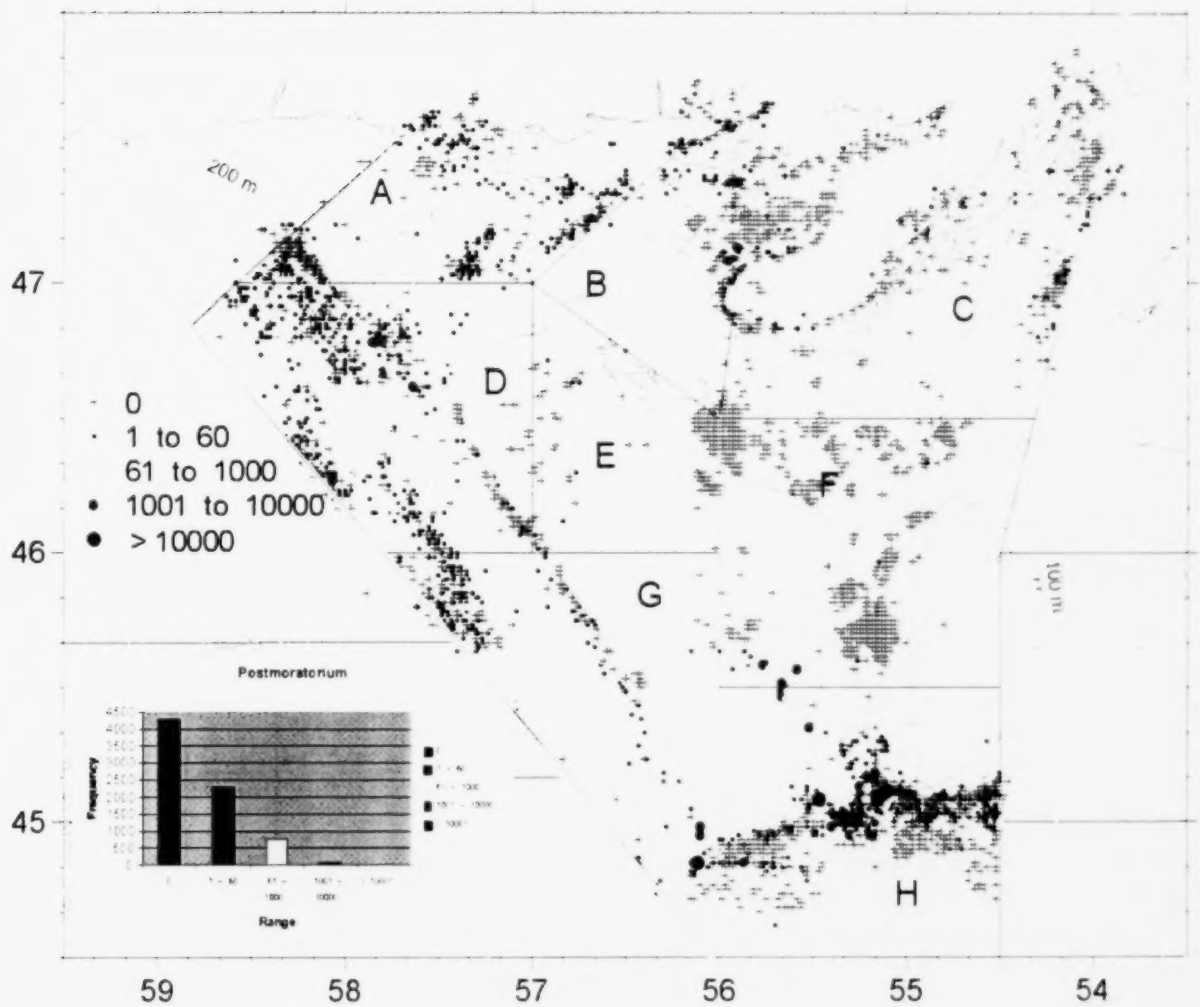
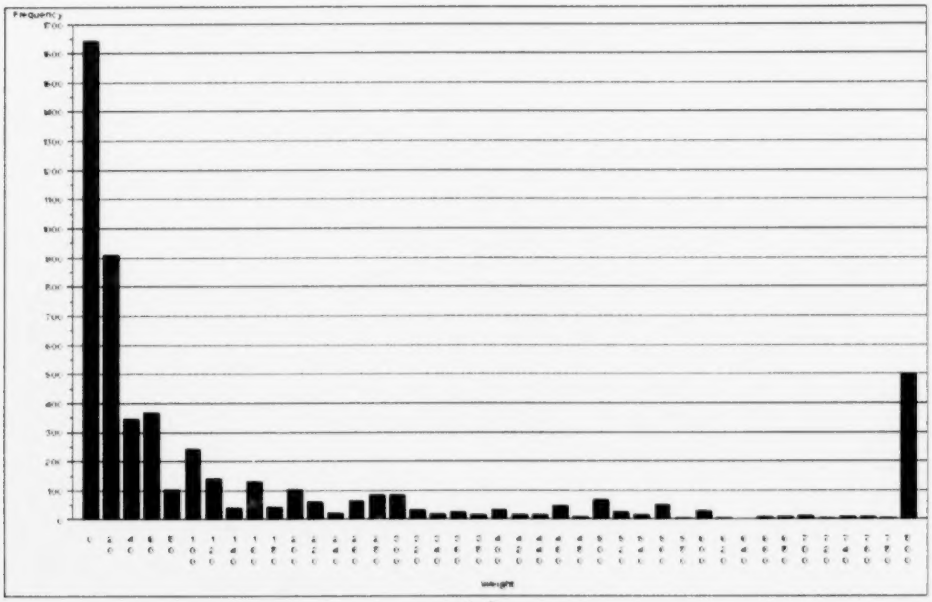
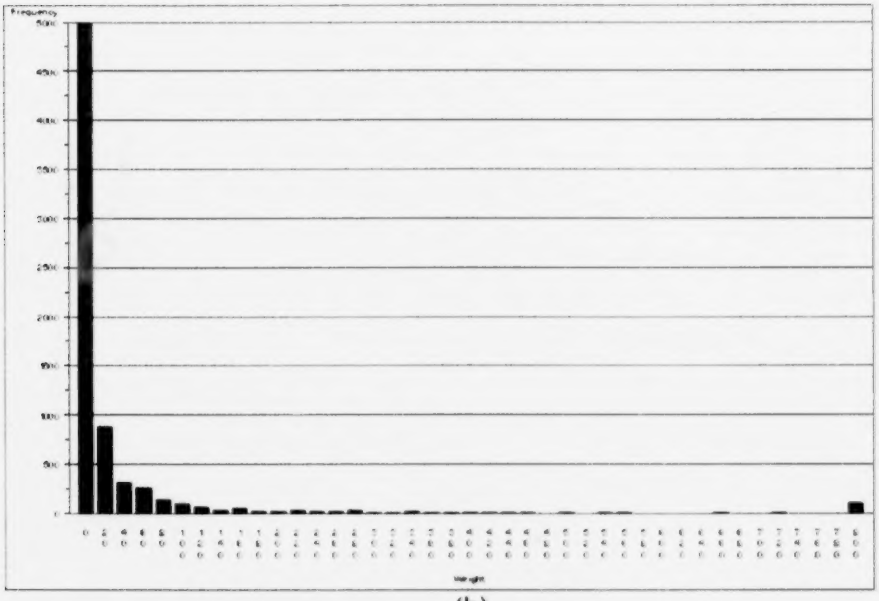


Figure 5. The distribution of observed total bycatches (kg) per set including zero sets, (a) 1985-1993 and (b) 1994-2001. The last bar includes all the sets of 790 kg or more.



(a)



(b)

Figure 6. Proportion of observed sets with cod and average weight per set (kg) in 1985-2001.

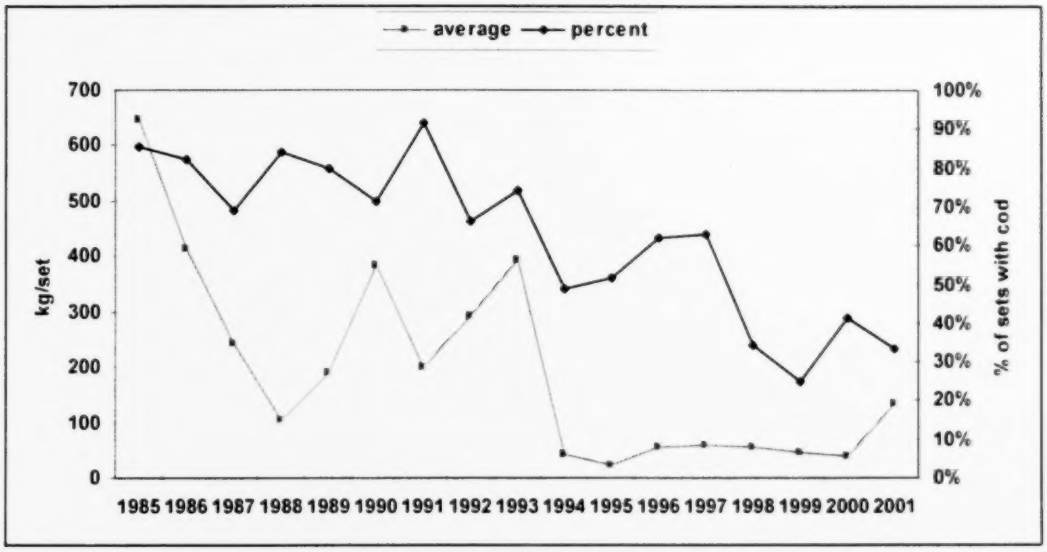


Figure 7. The yearly observed total bycatches from NAFO Subdiv. 3Ps by gear types.

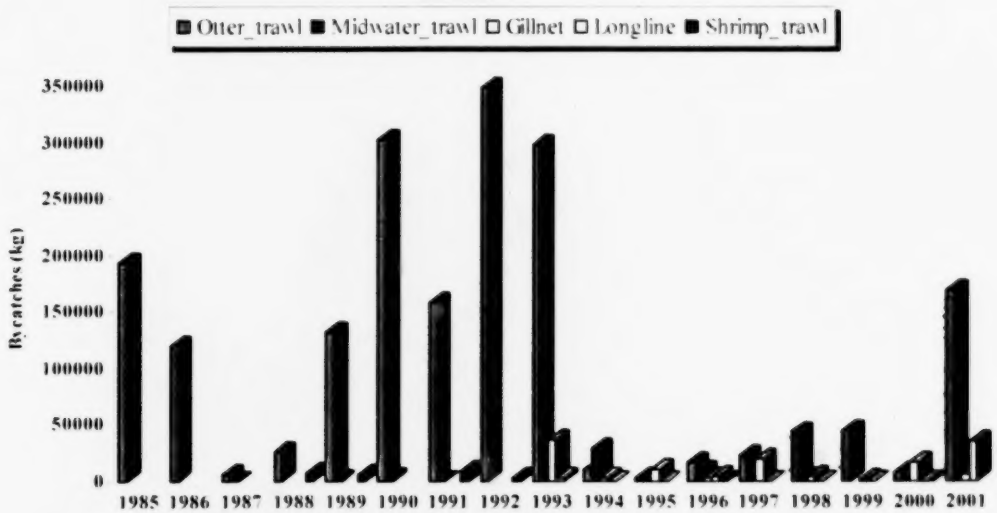


Figure 8. Yearly percent of observed total bycatches from NAFO Subdiv. 3Ps by unit areas.

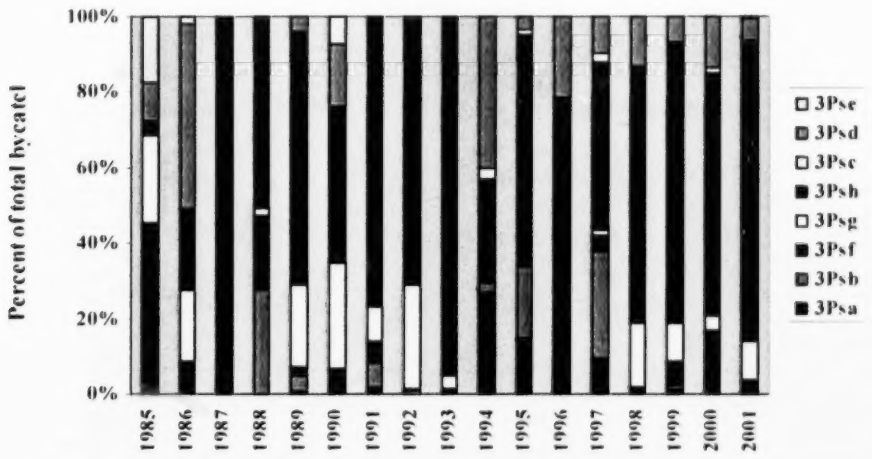


Figure 9. The bycatch per unit effort (BPUE) of the three commercial gears (kg per hour for otter trawl(OTbpue), per 1000 hooks for longline(LLbpue) and per 100 nets for gillnets(GNbpue)), average bycatch per set (kg) and percent of sets with cod by depth, 1993-2001 in observer data.

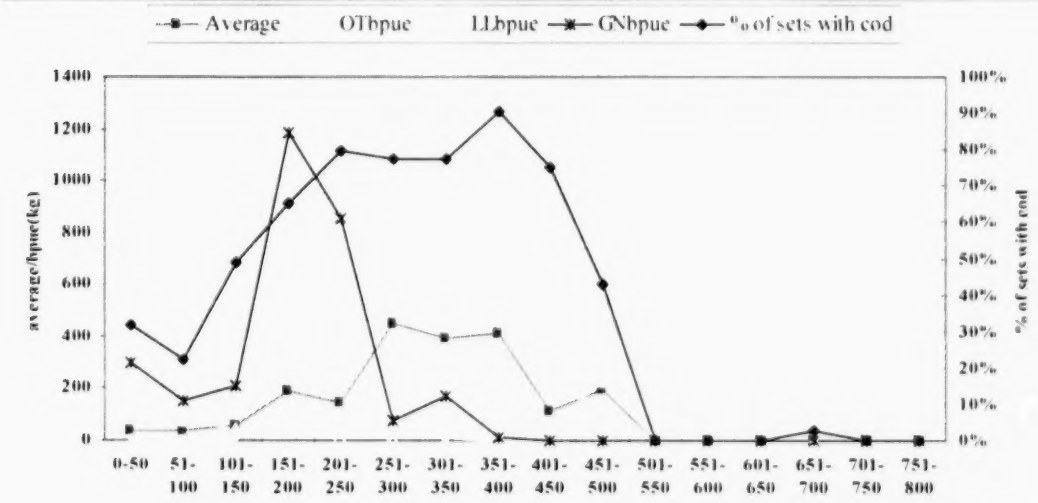


Figure 10. Observed average bycatches and proportion of sets with cod for depths <=500 m and >500 m, 1985-2001.